

The University of Alabama in Huntsville

Final Report for NASA Grant NAGW-2898  
(UAH Contract Number: 5-32871)

**“Far Ultraviolet Narrowband and Broadband Filters,  
Polarizers and Beamsplitters for Astrophysics and Astronomy”**

Submitted to:

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By:

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## **1. GOALS**

The goal of the funded research was to design and fabricate the following far ultraviolet (FUV) coatings:

1. Narrowband filters with bandwidths of less than 3 nm and a peak transmittance higher than 50%. The filters have the out-of-band rejection of better than 0.0001%.
2. Broadband filters with bandwidths from 10 - 20 nm, a band transmittance greater than 50%, and the blocking of out-of-band wavelengths better than 0.00001%.
3. Polarizing beamsplitters with the intensity ratio of two polarization states of 100,000 on the output for randomly polarized input; bandwidths from 1-5 nm and blocking for out-of-band wavelengths to better than 0.00001%. Intensity beamsplitters with 40%-40%-20% ratio of reflectance, transmittance and absorptance, respectively.

## **2. ACCOMPLISHMENTS**

1. The FUV coatings fabricated under this funding either match or exceed all research goal requirements stated in the proposal (see reprints).
2. Two graduate students whose research topics are in the areas of far ultraviolet optical thin films and instrumentation were partially involved in this research. Dr. Jongmin Kim and Dr. Jung Ho Park successfully defended their Ph.D. dissertations in 1994 and in 1995, respectively.
3. Results of the research funded by this grant are published in conference and journal papers and in two book chapters (reprints attached).

## **3. NASA PROJECTS THAT BENEFITED FROM THIS RESEARCH**

1. "Self-Filtering Spatial Heterodyne Spectrometer Operating at 155 nm", University of Wisconsin Space Astronomy Laboratory.
2. " Self-Filtering NUVIEWS Broadband Telescopes Operating at  $140 \pm 5\text{nm}$  and  $175 \pm 5\text{ nm}$ ", Columbia University Astrophysics Lab.
3. "Self-Filtering NUVIEWS Narrowband Telescopes Operating at  $155 \pm 2.5\text{nm}$  nm and  $161 \pm 2.5\text{ nm}$ ", Columbia University Astrophysics Lab.
4. "Self-Filtering Lyman- $\alpha$  Coronagraph", NASA/MSFC.
5. "155 nm Narrow-Band Filter for the Prospective HST Advanced Camera", NASA/GSFC.

#### 4. ATTACHED REPRINTS

The detailed description of the research results is given in the following attached reprints:

- "Multiple Reflectors as Narrowband and Broadband Vacuum Ultraviolet Filters", M. Zukic and D.G. Torr, in *Selected Papers on Ultraviolet Optics and Technology*, Robert E. Huffman, ed., SPIE Milestone Series, Volume MS 80, 76-84, (SPIE Bellingham, WA 1993).
- "X-Ray, Extreme and Far Ultraviolet Optical Coatings for Space Applications", M. Zukic, D. G. Torr and J. Kim, in *Trends in Optical Engineering*, edited by Council of Scientific Research Integration, published by Research Trends, 1994.
- "Extreme and Far-Ultraviolet Narrow-Band and Broadband Filters", M. Zukic and D. G. Torr, in *Handbook of Optical Properties Volume 1: Thin Films for Optical Coating*, edited by R. Hummel and K. H. Guenther, 79-105, CRC Press (Boca Raton, FL 1995).
- "Optical Configurations of H I Lyman- $\alpha$  Coronagraph/Polarimeters" R. B. Hoover, S. Fineschi, A. B. C. Walker, R. B. Johnson and M. Zukic, *SPIE*, 1546, 1991.
- "Multilayer Thin Film Designs as Far Ultraviolet Polarizers", J. Kim, M. Zukic and D.G. Torr, Presented at the 1992 International Symposium on Optical Applied Science and Engineering (SPIE) Conference in San Diego, California, July 1992, Paper published in *SPIE*, 1742, 413-422, July, 1992.
- "Polarimetry of H I Lyman- $\alpha$  for Coronal Magnetic Field Diagnostics", S. Fineschi, R. B. Hoover, A. B. C. Walker, P. C. Baker, M. Zukic and J. Kim, Presented at the 1992 International Symposium on Optical Applied Science and Engineering (SPIE) Conference in San Diego, California, July 1992. Paper published in *SPIE* 1742, 1992.
- "Design and Fabrication of the All-Reflecting H-Lyman- $\alpha$  Coronagraph/Polarimeter", R. B. Hoover, R. B. Johnson, S. Fineschi, A. B. C. Walker, P. C. Baker, M. Zukic, and J. Kim, Presented at the 1992 International Symposium on Optical Applied Science and Engineering (SPIE) Conference in San Diego, California, July 1992. Paper published in *SPIE*, 1742, 1992.
- "Multilayer Thin Film Designs as Far Ultraviolet Retarders", J. Kim, M. Zukic, D.G. Torr and M.M. Wilson, Presented at the 1992 International Symposium on Optical Applied Science and Engineering (SPIE) Conference in San Diego, California, July 1992. Paper published in *SPIE*, 1742, 403-412, July, 1992.
- "Design and Fabrication of Reflection Far Ultraviolet Polarizers and Retarders", J. Kim, M. Zukic, M.M. Wilson and D.G. Torr, Presented at SPIE's 1993 Annual Meeting, International Symposium on Optical Instrumentation and Applied Science, July 11-16, 1993, San Diego, California, Paper published in *SPIE* 2010, 93-103, 1993.
- "Transparent Conductive Coatings in the Far UV", J. Kim, M. Zukic, J.H. Park, M.M. Wilson, C.E. Keffer and D.G. Torr, Presented at SPIE's 1993 Annual Meeting, International Symposium on Optical Instrumentation and Applied Science, July 11-16, 1993, San Diego, California, Paper published in *SPIE* 2010, 220-227, 1993.
- "Solar Far Ultraviolet Polarimetry with Multilayer Optics", S. Fineschi, R. B. Hoover, M. Zukic, J. Kim and A. B. C. Walker, Presented at SPIE's 1993 Annual Meeting,

- International Symposium on Optical Instrumentation and Applied Science, July 11-16, 1993, San Diego, California, Paper published in *SPIE 2010*, 1993.
- "Fabrication and Test of a Wide-Field H-Lyman- $\alpha$  Coronagraph Instrument", R. B. Hoover, A. B. C. Walker, S. Fineschi, P. C. Baker, J. Kim, and M. Zukic, Presented at SPIE's 1993 Annual Meeting, International Symposium on Optical Instrumentation and Applied Science, July 11-16, 1993, San Diego, California, Paper published in *SPIE 2010*, 1993.
- "Stray Light Analysis of a Reflecting UV Coronagraph/Polarimeter with Multilayer Optics", S. Fineschi, R. B. Hoover, P. C. Baker, M. Zukic, J. Kim, and A. B. C. Walker, Presented at SPIE's 1993 Annual Meeting, International Symposium on Optical Instrumentation and Applied Science, July 11-16, 1993, San Diego, California, Paper published in *SPIE 2010*, 1993.
- "Multilayer Thin Film Design for Far Ultraviolet Quarterwave Retarders", J. Kim, M. Zukic, D.G. Torr and M.M. Wilson, *Optical Engineering*, Submitted, 1994.
- "Reflective Filters for the Self-Filtering Narrowband Ultraviolet Imaging Experiment for Wide-Field Surveys (NUVIEWS) Project", J.H. Park, J. Kim, M. Zukic and D.G. Torr, Presented at SPIE's International Symposium on Optics, Imaging and Instrumentation, July 24-29, 1994 in San Diego, California. Paper published in *SPIE* 2279, 155-164, July 1994.
- "Multilayer Thin Film Polarizer Design Using an Induced Transmission and Absorption Method", J. Kim, M. Zukic, M.M. Wilson, J.H. Park and D.G. Torr, Presented at SPIE's International Symposium on Optics, Imaging and Instrumentation, July 24-29, 1994 in San Diego, California. Paper published in *SPIE* 2283, July 1994.
- "Depth Profiling Analysis of Aluminum Oxidation During Film Deposition in a Conventional High Vacuum System", J. Kim, J.J. Weimer, M. Zukic and D.G. Torr, *J. Vac. Sci. Technol. A*, 3062-3067, November 1994.